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ABSTRACT

An engineering graphics course offered at North Carolina State University for freshman engineering students is described. The course is divided into 14 units and the students are allowed to proceed at their own pace. The first 11 units comprise the required core; the remaining 3 units may be chosen from other areas such as computer graphics, visual thinking, vector geometry, and graphical mathematics. (MLH)

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SELF-PACED GRAPHICS WITH TRACK OPTIONS

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Abstract

Engineering graphics has been taught by the self-paced method to freshman engineering students at N. C. State for the past four years. This paper describes why the method is particularly suited to basic graphics by responding not only to different student abilities and past experiences, but also to their individual needs, interests and future goals.

The course has been divided into 14 units of instruction. The first eleven units comprise what has been termed the "Basic Eleven" and are considered essential for every student to master regardless of his engineering career. Students are permitted a choice, however, in the remaining 3 units of the course. Seven 3-unit "Tracks" have been developed which provide an introduction to other areas encompassed by graphics such as: computer graphics; visual thinking; graphs, diagrams and graphical mathematics; pictorial illustration; vector geometry; production drawings and descriptive geometry.

Approximately 500 students are enrolled in 15-18 sections of the course each semester. Evaluations indicate that students enjoy the method and are learning more at a higher level of proficiency than under the lecture-lab method.

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INTRODUCTION

An emerging trend that has evolved in education in recent years is the increasing use of self-paced instruction as an alternative to the more traditional lecture method. For the uninitiated, self-paced instruction is, in the simplest words, the concept of permitting the student to set his own schedule of completing successive goals (units of work) with a given proficiency. Of the most enthusiastic users of this new method are engineering educators who have found the method particularly suited to the subject materials basic to their courses. Interest has been exemplified at annual ASEE conferences as well as divisional and regional ASEE meetings where a good portion of the programs have centered around this and similar methods. Engineering educators have not only been leading proponents, but have made significant contributions in researching, developing and refining the method's general usage. For example, the names of Flammer, Koen, Hoberock, and Harrisburger are no doubt familiar in engineering as well as self-paced circles.

Yes, the method is a recently emerging trend, but the concepts and practice are not new. Its beginnings have been traced as far back as the late 18th century. The method's recent popular usage can be attributed to advances in educational psychology, learning theory, and the initiative of a courageous few to implement radical departures from tradition. Among the basic principles of educational psychology which the method employs are:

1. Individuals differ in their needs, interests, backgrounds, styles of learning, rates of learning, etc.

2. Learning occurs best when the individual knows specifically what he is expected to learn and the limits within which he must apply himself.
3. Learning of future skills is dependent on how well prerequisite skills are learned. Otherwise, what we think is learning might actually be an accumulation of ignorance.
4. Success and positive reinforcement are better motivators of learning than failure and punishment.
5. Immediate feedback reduces the chances of accumulation of ignorance and further development of undesirable skills.
6. A complex task is learned best when broken down into small mentally digestible sub-tasks.

Engineering design graphics instruction is no exception to the trend. Indeed the method has been adapted to graphics instruction at several engineering schools. The intent of this paper is to describe how North Carolina State University has adapted the self-paced method to meet the unique needs of its own situation. Although only one person is presenting this paper, the cooperative effort of all faculty has effected the course's evolution from the "Model-T" days to the present [illegible], streamlined "Cadillac." Without their input, suggestions, critici[illegible] labors and patience this paper and the course would not have been possible. Hopefully, the ideas presented herein will be applicable at other institutions.

THE EVOLUTION

NCSU has offered self-paced instruction in its freshman engineering

graphics course for four years. The course, Engineering Graphics I, E 101, is required of all freshman engineering students. It is a 2-hr. course covering a 15-1/2-week semester. A typical class meets twice per week for one hour at the first meeting and 2 hours at the second meeting.

Prior to self-paced instruction a major problem was the difference among entering freshmen in the extent and quality of their previous experience in graphics. Approximately 30 percent had high school experience ranging from as little as several weeks to as much as 3 years. In addition, some students had practical work experience as draftsmen. On the other hand, the remaining 70 percent had no previous experience either because their high school did not offer drawing courses or because the student did not elect to take the high school course. Moreover, for those who had previous drawing, the instructional quality varied both with the high school and the instructor.

The only means for acknowledging individual differences was to offer students with prior experience an opportunity to exempt the course by successfully completing credit-by-exam. Those students who attained the minimum cut-off score on the exam were given credit for the course toward graduation. This method, however, had at least two shortcomings:

1. If the student passed the exam he was given credit for the course but no grade and, therefore, no quality points. Many of these students enjoyed graphics and could have earned an easy "A" thereby improving their overall G.P.A.

2. If the student failed the exam, he had no option but to complete the course in the same way as those students who had no previous experience. Many, however, could have passed the exam with only a little more instruction. Credit-by-exam did not distinguish the grey areas.

The extent and quality of previous experience, although a major difference, is not the only way in which engineering students differ. Other significant differences which can have a profound effect upon the graphics students are the variances in the students' innate ability to visualize spatial relationships and their manual dexterity with drawing instruments. Another problem of significant proportions is that a lecture course must be keyed to the "average" student. Thus the lectures bore the rapid students who have already studied and completed the work being presented, and are meaningless to the slow students who have not yet progressed to the state where they can understand and gain knowledge from the presentation. Self-paced instruction therefore seemed to be a solution to at least these problems.

In the Fall of 1971, three instructors administered one section apiece of what might be considered a crude self-paced course in graphics. We referred to it as our "Model-T." Primitive as it was, the method received overwhelming acceptance among students. Students were not only finishing the course earlier (some in as few as six weeks) but were covering the same materials at a higher level of mastery than under the lecture-lab method as proven by the difference in final examination scores between students under both methods. Contrary to our expectations,

students enjoyed the independence and maturity demanded of the method. Approximately 91% said that they would recommend the course to their friends if it were offered in the same way in the next semester.

Spurred on by the enthusiasm generated by positive response, the course has been continuously retried, retested, revised and refined. The growth of the course may be illustrated by the facts that 8 faculty are currently teaching 18 self-paced sections of basic graphics to over 500 students each semester. Class rolls also indicate that an increasing number of students from various curricula outside of engineering are electing the course. Self-paced materials have grown from the "Model-T" version: a 42-page, 9-unit, self-contained manual, to the "Cadillac" version: eleven color-coded basic units and 7 optional 3-unit tracks comprising several hundred pages of instructions, illustrations and worksheets.

THE PRESENT COURSE

Units

The course content of Engineering Graphics I has been divided into a total of 14 units of instruction. The first eleven units comprise what is termed the "Basic Eleven," and cover the basic concepts and skills considered essential for every student to master as a minimum regardless of his future engineering goals. Figure 1 lists the titles of the "basic eleven" units as well as the average times to complete each of them.

	UNIT	AVERAGE TIME TO COMPLETE	SCHEDULED COMPLETION DATE
1.	Orientation	1 Day	_____
2.	Lettering	1/2 Week	_____
3.	Instruments	1/2 Week	_____
4.	Geometric Constructions	1/2 Week	_____
5.	2-Dimensional Sketching	1 Week	_____
6.	3-Dimensional Sketching (Isometric Pictorials)	1-1/2 Weeks	_____
7.	Orthographic Projection	1-1/2 Weeks	_____
8.	First Auxiliaries	1 Week	_____
9.	Second Auxiliaries	1 Week	_____
10.	Sections and Conventions	1-1/2 Weeks	_____
11.	Basic Dimensioning	1-1/2 Weeks	_____

Figure 1. The "Basic Eleven"

Figure 1 is excerpted from the first unit, Orientation, which every student receives and retains for reference throughout the course. The "Average Time to Complete" each unit is the time, based on past experience, in which the average student, working at a normal pace, should be able to complete each unit. Although the time is shown in weeks, the actual time can be converted to hours. Under the semester system, a student is expected, as a rule-of-thumb, to spend a total of 3 hours per week (inside and outside of class) for each credit hour he is taking. Graphics carries 2 semester-hours credit. Therefore, one week would be the equivalent of approximately 6 hours of work. "Scheduled Completion Dates" are the dates the units would be completed if students consume the average time. Neither the "dates" nor the "times" are mandatory but are given to the student to help him gauge

his own progress.

Students must master each unit at a specified level of proficiency before they are allowed to proceed to the next unit. Proficiency levels vary from 80% to 100% mastery depending upon the importance of the unit to the students' future engineering careers as well as how necessary the unit is deemed to the mastery of future units. For example, the unit on lettering requires 80% proficiency, whereas the unit on orthographic projection requires 90% proficiency.

Units are color-coded by printing all the instructional materials, exercises, and proficiency tests for a given unit on the same color paper. Different units are different colors. Color-coding not only adds variety for the student, but it also provides the instructor quick visual identification of units as he roams about a classroom of students since most students are at different progression points in the course.

Tracks

Individuals differ in more ways than their learning pace. Engineering students also differ in their needs and interests, dependent upon their future goals. Traditionally the first course in engineering graphics at NCSU covered the fundamentals and culminated with either a set of working drawings or a design project. Engineering graphics, however, encompasses a broad spectrum of both analytical as well as representational and communicative concepts. Although elective courses were offered in Vector Geometry, Computer Graphics, etc., students seldom opted them. At least one reason could have been that students

did not know enough about the elective course to make a choice. Since their only exposure to graphics had been in the fundamentals course where graphics concepts were primarily representational and possibly less stimulating to those with analytical interests, any course flavored with the term "graphics" was associated with that initial experience.

To meet varied student needs as well as to introduce other, perhaps more interesting areas of graphics, seven 3-unit tracks were developed. Each track introduces the student to at least one additional area encompassed by graphics. After the student has completed the "Basic Eleven" he may choose a track, each of which is designed to consume approximately 3-1/2 weeks or 21 hours of study. The title of the seven available tracks are listed below in Figure 2.

TRACK	STUDENT CHOICE %
Production Drawings	14%
Computer Graphics	12%
Spatial Geometry	
Graphs, Diagrams and Graphical Mathematics	20%
Pictorial Illustration	
Visual Thinking	40%
Vector Geometry	14%

Figure 2. Tracks and percent of students selecting track in 1975 Spring semester

Figure 2 also shows the percentage of students who opted the 5 tracks available in the 1975 Spring semester. The percentages indicate that student needs and interests do differ, and when given the opportunity they will select areas of graphic study other than the

more traditional "production drawing" area. Another point not illustrated in Figure 2 is the fact that some students chose and completed 2 tracks although they had already earned their "A" by completing just one track.

Who is to say what the student should learn in graphics after he has completed the fundamentals (basic eleven)? Although production drawings might be beneficial to the student pursuing a degree in mechanical engineering with an emphasis on design, a civil engineering student might benefit more by being introduced to graphical techniques for analyzing loads in members of a truss, while an electrical engineering major might find graphical mathematics both interesting and helpful.

After being introduced to the area by means of the track, the student may wish to pursue a more in-depth study. NCSU offers full-semester elective courses in all but one (pictorial illustration) of the tracks. Tracks, however, are not prerequisite for elective courses. Perhaps the track concept will help provide the stimulus necessary to place graphics back in the mainstream of engineering education while at the same time further meeting the individual needs of engineering students.

CONDUCT OF THE COURSE

Orientation

The first two class meetings are used solely to orient the new student to self-paced instruction, the course material, conduct of the course, grading, freedoms, restrictions, etc. The lecture-discussions are based on the contents of Unit 1 (Orientation) which the student

keeps for reference throughout the semester. To make sure everyone understands the "rules of the game," a short 10-minute proficiency test is given to the entire class after which the answers are discussed in detail. After the second class meeting there are no further lectures.

Credit-by-exam

During the first two meetings the various options of credit-by-exam are also discussed. As mentioned earlier, approximately 30% of the students have had previous graphics training. Interested and qualified students are given opportunities to take the exam early in the semester. The exam may be taken whenever (up to the middle of the semester) the student feels ready but may be attempted only once. If the student does not pass the exam, there is no penalty and he completes the course just as any other student. If the student does pass, however, he has three options:

1. Accept credit for the course as a requirement for graduation. Under this option the student receives credit only and no grade or quality points.
2. Decline credit-by-examination (if the exam is taken during the first two weeks) and serve as a proctor in the course. This option allows the student not only to receive credit but also an "A" and quality points if he performs adequately. A side benefit worthy of mention is that these student proctors really learn a lot more about graphics as they attempt to help other students in the class.

3. Decline credit-by-examination and take the course just as any other student. This option appeals to some students who feel that they can complete the course relatively soon (4 - 8 weeks), thereby receiving credit as well as an "A". As an additional option, this student may drop the course any time before mid-semester if he decides he had rather receive credit-by-examination.

Completing the Units

During the first week or so a general hesitancy prevails on the part of students. For most, self-paced instruction is quite different from their more traditional classroom experiences. Prior conditioning has not required the student to be responsible for his own success and there exists a disbelief that he is being permitted the freedom to steer his own course.

To help alleviate student anxieties in his new environment, the first two units are purposely designed to be relatively short and simple. Once the student discovers that the instructor, although not lecturing, is always available to help him with his problems when he has them, that he can work at his own pace, and take tests when he is ready and as many times as he likes to make the grade that he desires, the hesitancy gradually dispels.

Progression through a typical unit is essentially the same for all units. The student checks out a unit (one at a time) from his instructor or proctor who records the transaction on his class progress record. Students have been cautioned early in the course to begin a

new unit by carefully studying the unit's objective and rationale. The objective tells the student exactly what he should be able to do after completing the unit, at what mastery level he must perform and the freedoms and restrictions that will be imposed upon him (time limits, use of text, etc.). In summary, the objectives define the student's task and give him a goal to shoot for. The rationale tells the student the reasons for and importance of the material in the student's engineering education and has as its central purpose, motivation.

With the objective and rationale clearly in mind, the student proceeds with the instructional exercises. Exercises progress from easy to difficult, from simple to complex, culminating with exercises similar to the proficiency tests. Not all the exercises are required, however, if the student feels that he is competent enough to skip them. He is the judge. Solutions to the initial exercises are given at the end of units so that the student can compare his own work, receive immediate feedback, and correct his errors before proceeding further.

Solutions, however, are not provided for the last exercise in each unit. The last exercise is a "self-test" and is similar in difficulty and complexity to the proficiency test. When the student feels that he has mastered the objectives of the unit, whether or not he has completed all the previous exercises, he attempts the self-test. After his instructor examines the self-test with him, the student is allowed to take the proficiency test.

Several different proficiency tests have been developed for each unit. The instructor determines the test that will be administered to

a given student on a given day. Each test is relatively short and has been designed to measure whether or not the student has mastered the objectives specified for the unit. Students may take the test either in class or during the instructor's designated office hours. As soon as the student completes the test he and his instructor together examine it to determine proficiency. Immediate and personal feedback is thus provided the student.

If the student has demonstrated the level of proficiency specified in the objectives for the unit, he is given credit for the unit. He then turns that unit in and checks a new one out. If not, he restudies and retakes different versions of the test until he does prove proficiency. No penalty is imposed for not passing. Students soon realize, however, that taking tests repeatedly is an unprofitable use of time. A serious effort, therefore, is made by most students to prove proficiency on the first or at least second attempt.

Exempting the Exam

A major problem that is typically associated with self-paced instruction is the human tendency to procrastinate. Although procrastination is evident under other instructional methods (in fact, in all human tasks), the problem is especially evident when the student is first given freedom to determine his own pace. An incentive technique is used at NCSU to help overcome this problem. The incentive is exemption from the final exam. If the student finishes all 14 instructional units (the "basic eleven" plus a 3-unit "track") two weeks prior to the last day of classes, he automatically receives an "A" in the course without

having to take the final exam. For approximately 75% of the students, exam exemption is reward enough for setting a determined, steady pace to meet that goal. In fact, it is not unusual for students to finish by midsemester or earlier, thereby relieving themselves from attending class for the remainder of the semester.

GRADING

Unit Grades

Students do not receive a numerical or letter grade for units they complete. Instead, a check mark is recorded in the instructor's record book if the unit has been completed with at least the minimum level of proficiency. Proficiency is based solely on the students' performance on the unit tests.

Final Grades

Final grades (A, B, C or No Credit) are based on the number of units completed. The exam, also, is considered as one unit for purposes of determining the final grade for those students who do not exempt it. Each unit not completed reduces the final grade by one letter grade. Thus, an "A" is earned by completing all 15 units, a "B" for completing 14 units, and a "C" for completing 13 units.

A student receives a grade of "No Credit" (NC) if he completes less than 13 units. Although the NC student must repeat the course, the concept of self-paced instruction permits him to start essentially where he left off in the previous semester. The grade of "Incomplete" (IN) is discouraged except in unusual or extenuating circumstances.

SUMMARY

Self-paced instruction is indeed a trend in engineering education that is gaining increasing impetus. As with any innovation its implementation requires a long preparation time, much patience, and a lot of work. For those who have tried it, however, the enthusiasm generated by its positive effects has been reward enough to persist in its growth and refinement.

Implementation of self-paced graphics instruction at NCSU has evolved into a method that fulfills the needs of the course, the instructor, and—most of all—the student. Individual differences between students, especially those differences related to previous experience, can now be recognized and administered to. No longer must the instructor aim his instruction toward the average in hopes that the more capable student will not be bored nor the less capable, lost.

Individual students are also able to find some degree of congruence with their needs, interests, and future goals during the last 3-1/2 weeks of the course. After mastering the basic course, students have a choice of 7 different tracks which offer an introduction to many of the non-traditional areas encompassed by graphics. Besides offering variety, the tracks also offer an introduction to NCSU's elective graphics courses where a more in-depth coverage is possible. The track concept is easily adapted to self-paced methods, whereas it would be almost impossible under more rigid traditional methods.

One of the greatest rewards stemming from self-paced instruction is the enthusiasm that prevails in the classroom. Students as a whole

take satisfaction in being responsible for their own destinies and the accompanying sense of maturity. Periodic opinionaires also indicate student satisfaction with being required to master the material. The flexibility inherent in the method which allows the student to meet other commitments (for example, tests and term papers in other courses), as well as the informal classroom atmosphere and the individual student-to-teacher relationship are other frequent positive comments.

An initial resistance to self-paced instruction comes from teachers who are steeped in the tradition of the lecture-lab method. They tend to shudder at the idea that they may have to explain the same principle to 25 students at 25 different times. However, when they find out that they are explaining to students who know that they need to understand the principle, that are eager to learn, these same teachers realize that they are actually fulfilling their main function: to impart knowledge to all students. They find that they are getting to know each student as an individual rather than as a name on a roster and a body occupying some seat in the classroom. This then helps them adjust each explanation to fit a particular student's needs, personality, and prior knowledge. Almost all teachers, after experience with this method, become staunch supporters of self-paced instruction.

This paper is but one of many that have been presented since self-paced instruction has made its debut in engineering education. It further attests to the fact that the method can and does work with success as an alternate to more traditional methods. Further still, it can be effectively implemented on the freshman level in basic engineering courses.